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P3 5 The Parsec Paradox

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Abstract

In this paper, we have worked out the speed at which the Millennium Falcon would have to travel in order to complete the Kessel Run in 12 parsecs, as Han Solo supposedly did in the Star Wars franchise. It was determined, using length contraction, that Han Solo would have to pilot the Millennium Falcon at 0.8 times the speed of light. It was further calculated that Han would have experienced 48.9 years go by in the time that it took him to complete the Kessel run.

Introduction

In the Star Wars universe, the Kessel Run is an infamous 20 parsec route that smugglers use [1]. Han Solo, pilot of the Millennium Falcon, famously "made the Kessel Run in twelve parsecs"[1]. A parsec is a unit of distance, hence why the use of parsecs as a measure of time in this quote has long been debated by physicists as being incorrect. In this paper, we assume that this was in fact not a mistake and that "parsecs" was actually intended as a unit of distance.

The Millennium Falcon is a fictional spaceship that can travel at 'hyperspeed' [2]. If we constrict the Star Wars universe to obey the physics of our universe and assume that the Millennium Falcon can travel close to the speed of light, but not faster than it, then we can calculate how fast Han Solo would actually have to be travelling in order to experience the Kessel Run route as length contracted to 12 parsecs.

Length Contraction

Einstein's theory of special relativity tells us that an object travelling close to the speed of light appears to contract in its direction of motion when observed by a stationary observer [3]. The equation for such a length contraction is as follows [4]:

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}} \tag{1}$$

Where L is the length of the Kessel Run in the reference frame of the Millennium Falcon, in this case 12 parsecs (where 1 pc $= 3.086 \times 10^{16}$ m [5]). L_0 is the length of the Kessel Run as seen by a stationary observer, in this case 20 parsecs. v is the velocity of the Millennium Falcon in ms^{-1}. c is the speed of light, where $c = 3 \times 10^8$ ms^{-1}.

In the movies, hyperspeed is depicted as faster-than-light travel. In reality, v cannot exceed c, as this would make the square root in Equation 1 negative, resulting in an imaginary length. For the purpose of this paper, we assume that the Millennium Falcon obeys the laws of physics and its velocity simply approaches the speed of light, rather than exceeding it. We therefore rearrange Equation 1 to determine what this speed would be:

$$v = \sqrt{c^2\left(1 - \frac{L^2}{L_0^2}\right)} \tag{2}$$

By rearranging for v and substituting in the values as discussed above, we calculate the velocity to be 2.4×10^8 ms^{-1}, or 0.8 times the speed of light.

Time Taken to Complete the Kessel Run

In the reference frame of a stationary observer, it would take the Millennium Falcon 81.5 years to complete the Kessel Run. This was calculated using Equation 3 [4].

$$\Delta t = \frac{L_0}{v} \tag{3}$$

Where L_0 is the length of the Kessel Run as seen by the observer, so $L_0 = 20$ parsecs, and v is the velocity of the Millennium Falcon, calculated the be $0.8c$.

Effects of Time Dilation

As well as experiencing length contraction, objects travelling close to the speed of light will also experience the effects of time dilation. The equation for time dilation is as follows [6]:

$$\Delta\tau = \Delta t\sqrt{1 - \frac{v^2}{c^2}} \tag{4}$$

Where $\Delta\tau$ is the time taken in Han Solo's reference frame. Δt is the time taken as seen by a stationary observer. v is the velocity of he Millennium Falcon, as before. Again, c is the speed of light.

Using $\Delta t = 81.5$ years, as previously calculated, and the other variables as before, the time taken for Han Solo to complete the Kessel Run, in his own frame of reference would be 48.9 years. Clearly, this is much longer than is depicted in the movies.

Conclusion

To conclude, in this real life application of the fictional Kessel Run scenario, Han Solo would have to be travelling at 0.8 times the speed of light in order to experience the Kessel Run as a distance of 12 parsecs, rather than 20 parsecs. A stationary observer would see Han Solo complete this in 81.5 years, while Han himself would have experienced the passing of 48.9 years. This is clearly much longer than is implied in the franchise. Perhaps the Millennium Falcon is able to travel much faster than the speed of light in the movies for dramatic purposes, as "making the Kessel Run in 48.9 years" doesn't quite have the same ring to it. Hence, George Lucas likely did not understand what a parsec is and chose to ignore the laws of physics for the sake of science fiction.

References

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